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417-R-GLMPORD-0057
Version 0.0

Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Geostationary Lightning Mapper (GLM)

Performance and Operational Requirements Document (PORD)

July 12, 2005

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

To verify the correct version of this document, please contact the GOES-R Series Configuration Management Office.

Geostationary Operational Environmental Satellite (GOES)
GOES-R Series
Geostationary Lightning Mapper (GLM)
Performance and Operational Requirements Document (PORD)

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/GLM

GLM PORD

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GLMPORD1	1	**1 Scope**
GLMPORD2	1.1	**1.1 Identification**
GLMPORD3	1.1.0-1	This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Geostationary Lightning Mapper (GLM).
GLMPORD4	1.2	**1.2 Mission Review**
GLMPORD5	1.2.0-1	The GLM is a single-channel, near-IR optical lightning detector, used to measure total lightning activity over the full-disk as part of a 3-axis stabilized, geostationary weather satellite system.
GLMPORD6	1.2.0-2	The GLM objectives are as follows: • Provide continuous full-disk lightning measurements for storm warning and nowcasting. • Provide longer warnings of tornado activity. • Accumulate a long-term database to track decadal changes in lightning activity.
GLMPORD7	1.2.0-3	The GLM instrument, designated as GLM in this document, provides event data to the GLM Ground System, designated as GLM-GS in this document, via the spacecraft communication system. The GLM-GS takes the GLM data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates calibrated and navigated data for the NOAA users. Radiometric calibration is performed before launch. The GLM-GS will be procured separately by the Government but will implement algorithms developed by the GLM contractor to satisfy GLM performance requirements.
GLMPORD8	1.3	**1.3 Document Overview**
GLMPORD9	1.3.0-1	This document contains all performance requirements for the GLM instrument and Ground Support Equipment (GSE). This document, the General Interface Requirements Document (GIRD), and the GLM Unique Instrument Interface Document (UIID) define all instrument-to-spacecraft interfaces for the GLM instrument.
GLMPORD10	1.4	**1.4 Terminology**
GLMPORD11	1.4.0-1	This document contains all performance requirements for the sensor except those labeled "TBD" and "TBR". The term "TBD," meaning "to be determined," applied to a missing requirement means that the contractor will determine the missing requirement in coordination with the government and the observatory contractor. The term "TBR," meaning "to be reviewed," implies that the requirement is subject to review for appropriateness by the contractor or the government. The government may change "TBR" requirements in the course of the contract.
GLMPORD12	1.5	**1.5 Definitions**
GLMPORD13 …	1.5.0-1	Throughout this document, the following definitions apply: <u>Background Image:</u> A scene derived from readout of all detector elements, or a selectable subset thereof.

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GLMPORD13 …	1.5.0-1	CONUS: Defined as a nadir-viewed rectangle 8.0215 x 4.8129 degrees, 5000 East/West x 3000 North/South kilometers, approximately in the geographic area of 10N-50N latitude and 60W-125W longitude. Detector sample: Digitized output of a single physical detector element. Eclipse: Defined as when the solar disk is completely occulted by the Earth or Moon, as viewed from the GOES satellite. Flash: Series of lightning pulses grouped by proximity in location and time. Full Disk: For the GLM, the Full Disk is defined by the Field of Regard Angle that precludes GLM observations from extending beyond the limb of Earth, including the effects of spacecraft orbit variations and attitude jitter. Fully Functional Configuration: Being able to perform the following functions on-orbit: lightning detection; acquisition of sensor health and status data; generation of science, and health and status data streams; and reception and execution of command and control data. Geo-location: Conversion of detector element location to Earth-fixed latitude and longitude. Geo-location Error: The difference between the estimated and true latitude and longitude location of a detected lightning event. Ground Sample Distance: The angular separation between the centroid of adjacent detector elements measured in microradians in the N/S and E/W directions. GSD is converted to spatial resolution in km at the sub-satellite point. Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle. Navigation: The act of determining the location of each detector element in angle space from which geo-location is determined. Navigation Error: Refers to the angular error of location of each detector element in angle space. Precision: Refers to the standard deviation of a statistically meaningful number of samples of a measurement. Pulse: An optical signal generated by lightning whose nominal duration is on the order of 1 ms. Transfer Orbit: The sequence of events that transpires to establish the GOES R series satellite on-station after the GOES R series satellite has separated from the launch vehicle. Unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronics unit and sensor unit.
GLMPORD14	1.5.0-2	All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the GLM PORD, GLM UIID, and the GIRD.

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GLMPORD15	1.5.0-3	The requirements in this GLM PORD pertain to the GLM ‘system’ which may include optics, detectors, signal processing electronics and software, and ground processing. The GLM contractor is not responsible for the whole GLM-GS, but certain GLM specifications, e.g., geolocation, will require some level of ground processing after collection but before data distribution.
GLMPORD16	1.5.0-4	All requirements apply over the entire life of the GLM. Data performance requirements, such as geo-location, apply to data after all ground processing.

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GLMPORD17	2	**2 Applicable Documents**
GLMPORD18	2.0-1	The following form a part of this specification to the extent specified herein. GOES-R General Interface Requirements Document, NASA-GSFC, Document Number 417-R-GIRD-0009 GLM Unique Instrument Interface Document (UIID), NASA-GSFC, Document Number 417-R-GLMUIID-0058 CCSDS Recommendation for Space Data System Standards, Lossless Data Compression, CCSDS 121.0-B-1, May 1997. Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001, June 21, 1996 General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document Number MIL-A-83577B, February 1, 1988 Space Mechanisms Handbook, Document Number NASA TP-1999-206988 General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components, Document Number GSFC GEVS-SE, June1, 1996 AFSPCMAN 91-710, Range Safety User Requirements, July 2004 Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522, Sept. 4, 1992

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GLMPORD19	3	**3 GLM Sensor Requirements**
GLMPORD20	3.1	**3.1 GLM Functional Requirements**
GLMPORD21	3.1.1	**3.1.1 GLM Modes**
GLMPORD259	3.1.1.0-1	The contractor may propose additional modes for GLM.
GLMPORD22	3.1.1.1	**3.1.1.1 Safe Mode**
GLMPORD23	3.1.1.1.0-1	The GLM **shal**l implement a Safe Mode which is a thermally, electrically and optically safe configuration that protects the instrument from the spacecraft and the environment.
GLMPORD24	3.1.1.1.0-2	The GLM **shall** be maintainable in Safe Mode for an indefinite period of time.
GLMPORD25	3.1.1.1.0-3	The GLM **shall** enter Safe Mode upon receipt of a ground command, or upon receipt of an autonomous safe mode command from the observatory, or upon detection of internal faults capable of causing permanent damage to the instrument.
GLMPORD26	3.1.1.2	**3.1.1.2 Normal Operational Mode**
GLMPORD27	3.1.1.2.0-1	The GLM **shall** be in a fully functional configuration while in Normal Operational Mode.
GLMPORD28	3.1.1.3	**3.1.1.3 Diagnostic Mode**
GLMPORD29	3.1.1.3.0-1	The GLM **shall** implement a Diagnostic Mode.
GLMPORD30	3.1.1.3.0-2	The Diagnostic Mode **shall** contain the following Functions TBD:
GLMPORD31	3.1.1.3.0-3	The Contractor will define the capabilities and functions of the Diagnostic Mode.
GLMPORD32	3.1.1.4	**3.1.1.4 Survival Mode**
GLMPORD33	3.1.1.4.0-1	The GLM **shall** implement a Survival Mode in which all power is off except for survival heater power, and only passive telemetry is available.
GLMPORD34	3.1.1.5	**3.1.1.5 Mode Transitions**
GLMPORD35	3.1.1.5.0-1	The GLM **shall** transition from any defined mode to any other defined mode upon
GLMPORD36	3.1.2	**3.1.2 On-Orbit Operations**
GLMPORD37	3.1.2.1	**3.1.2.1 Zones of Reduced Data Quality**
GLMPORD38	3.1.2.1.0-1	The GLM **shall** meet all operational and performance requirements for all detector elements whose distance from the center of the un-eclipsed portion of the sun is greater than 10° (TBR).
GLMPORD39	3.1.2.1.0-2	For all detector elements whose distance from the center of the un-eclipsed portion of the sun is between 5° and 10° (TBR), the GLM **shall** meet all requirements, except for a two times (TBR) degradation in the SNR, detection efficiency and false alarm rate specifications.
GLMPORD40	3.1.2.2	**3.1.2.2 Solar Intrusion**

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GLMPORD41	3.1.2.2.0-1	The GLM **shall** withstand Sun in the field-of-view for one hour (TBR) without damage.
GLMPORD42	3.1.2.3	**3.1.2.3 Eclipse**
GLMPORD43	3.1.2.3.0-1	The GLM **shall** operate continuously through eclipse periods.
GLMPORD44	3.1.2.4	**3.1.2.4 Post-Maneuver**
GLMPORD45	3.1.2.4.0-1	The GLM **shall** meet all detection, coverage and measurement requirements after spacecraft attitude is within specification following yaw-flip.
GLMPORD46	3.1.2.4.0-2	The GLM **shall** meet geo-location requirements after spacecraft attitude is within specification following yaw-flip.
GLMPORD47	3.1.2.4.0-3	The GLM **shall** meet all requirements after spacecraft attitude is within specification following a station-keeping maneuver.
GLMPORD48	3.1.2.4.0-4	The GLM **shall** meet all requirements within 10 minutes (TBR)of GLM turn-on after being in on orbit storage.
GLMPORD49	3.2	**3.2 GLM Performance Requirements**
GLMPORD50	3.2.1	**3.2.1 GLM Coverage Requirements**
GLMPORD51	3.2.1.0-1	The GLM **shall** provide continuous lightning detection over the full disk.
GLMPORD52	3.2.1.0-2	The GLM **shall** provide a near circular field of regard, centered at the sub-satellite point, that does not extend beyond the Earth's limb, including margin for navigation errors.
GLMPORD53	3.2.1.0-3	The GLM **shall** provide a Ground Sample Distance of 10 km (threshold) at the sub-satellite point, with a goal of 0.5 km (TBR). Discussion: Eight to ten km resolution captures the updraft kinematics driving the storm. Too high a resolution sub-samples the updraft, and the trends are not as clear.
GLMPORD54	3.2.2	**3.2.2 GLM Spectral Requirements**
GLMPORD55 …	3.2.2.0-1	The GLM **shall** detect radiation centered at 777.4 nm, with a bandwidth at full-width half-max of TBD nm. The lightning spectrum is shown in Figure 1 below. Figure 1. Lightning Spectrum

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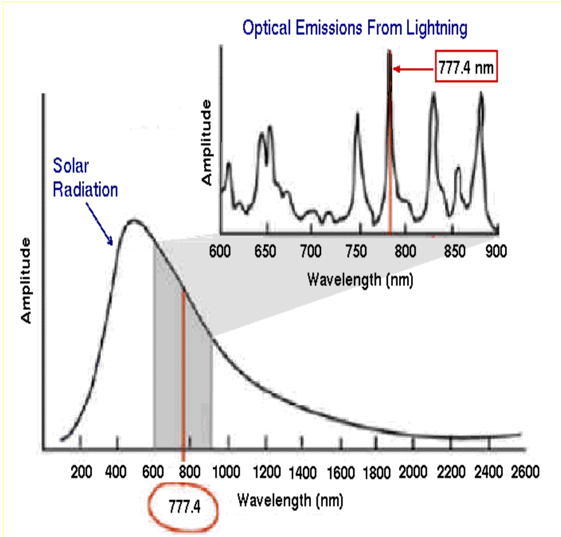
GLMPORD55 3.2.2.0-1



This figure comes from an untitled slide package provided by Hugh Christian.

Discussion: This is the wavelength band used on the TRMM Lightning Imaging Sensor (LIS), and the MSFC LMS study.

GLMPORD63 3.2.3

3.2.3 GLM Lightning Detection

GLMPORD64 3.2.3.1

3.2.3.1 GLM Basic Detection Requirements

GLMPORD65 3.2.3.1.0-1 GLM lightning detection **shall** be autonomous.

GLMPORD66 3.2.3.1.0-2 The GLM system **shall** provide the geo-location of each detected lightning event.

GLMPORD67 3.2.3.1.0-3 The GLM **shall** measure the intensity of each detected lightning flash to an accuracy of 10 percent (1σ) (TBR), as determined from the pre-launch ground calibration.

Discussion: Intensity data provides information on the energy and characteristics of the lightning flash and can be used in instrument diagnostics.

GLMPORD68 3.2.3.1.0-4 The GLM **shall** measure the background level of the detected lightning event.

Discussion: Background level and intensity are necessary for verifying event detection, and the background is already computed as part of the process.

GLMPORD69 3.2.3.2

3.2.3.2 GLM Sensitivity and Dynamic Range

GLMPORD70… 3.2.3.2.0-1 The GLM **shall** detect optical lightning pulses on the order of 1millisecond in duration. The temporal variation of a lightning pulse is shown in Figure 2 below.

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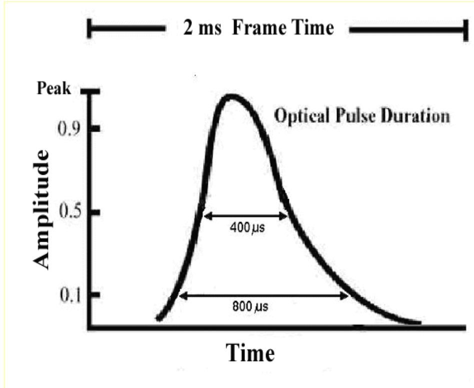
GLMPORD70	3.2.3.2.0-1	 Figure 2. Lightning Pulse Duration Flashes are composed of multiple pulses. While pulse duration is on the order of a millisecond, flash duration is typically on the order of one second.
GLMPORD73	3.2.3.2.0-2	The GLM **shall** detect lightning flashes with energies as small as 4.7 $\mu J/m^2$-sr (3.8 $\mu J/m^2$-sr goal). Discussion: This is the threshold used on the TRMM Lightning Imaging Sensor (LIS).
GLMPORD74	3.2.3.2.0-3	The flash detection efficiency **shall** be at least 70 percent at end of life (TBR) (99% goal). Discussion: This quantity is computed as the fraction of total lightning flashes detected from the ground that are also detected by the GLM. The time span for this computation is 24 hours. (TBR)
GLMPORD75	3.2.3.2.0-4	The False Alarm Rate **shall** be less than 5%. This quantity is computed as the fraction of total lightning flashes detected by the GLM but not detected from the ground. The time span for this computation is 24 hours. (TBR)
GLMPORD76	3.2.3.2.0-5	The GLM **shall** provide an event dynamic range > 100, after background subtraction.
GLMPORD77	3.2.3.2.0-6	Deleted
GLMPORD78	3.2.3.2.0-7	A desirable option is the detection and quantization of continuing current. Discussion: The continuing current signature originates from a sequence of illuminated detector elements with diminishing intensity lasting from tens to hundreds of milliseconds.
GLMPORD79	3.2.3.3	**3.2.3.3 GLM Command and Control Requirements**
GLMPORD80	3.2.3.3.0-1	Receipt and processing of commands and data to the GLM **shall** not interfere with data collection in any mode.
GLMPORD81	3.2.3.3.0-2	The GLM **shall** execute commands to individually enable and disable each autonomous function.
GLMPORD82	3.2.3.3.0-3	The GLM **shall** initiate all commanded mode transitions in no more than 5 seconds (TBR) after receipt of command.
GLMPORD83	3.2.3.3.0-4	The GLM **shall** make limits and triggers of autonomous functions changeable by command.

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GLMPORD84	3.2.3.3.0-5	The GLM **shall** transition from its current mode to any other mode without causing permanent damage to itself.
GLMPORD86	3.2.3.3.0-6	The GLM **shall** indicate the instrument mode in housekeeping telemetry.
GLMPORD87	3.2.3.3.0-7	The GLM **shall** provide command and housekeeping telemetry functions in all powered modes.
GLMPORD88	3.2.3.3.0-8	The GLM **shall** provide command-selectable focal plane sub-arrays for priority lightning event detection (TBR).
GLMPORD89	3.2.3.3.0-9	The GLM **shall** provide a detection threshold that is adjustable by command.
GLMPORD90	3.2.3.3.0-10	The GLM **shall** provide image areas selectable/de-selectable by command for prioritized image transmission.
GLMPORD91	3.2.3.4	**3.2.3.4 GLM Geolocation Requirements**
GLMPORD92	3.2.3.4.0-1	The GLM s**hall** provide for geolocation, of all data from each detector element transmitted to the ground.
GLMPORD93	3.2.3.4.0-2	All geolocation requirements listed herein refer to location error of the GLM detector elements; i.e., the requirements apply to the end-to-end system, taking all instrument, spacecraft, and ground processing effects into account. Unless otherwise specified, all navigation requirements in this document are specified in microradians, 3-sigma, and refer to all hours of operation. In addition, for the purposes of this section, 3-sigma is defined as the average +/- 3 times the square root of the variance for a population of 100 consecutive observations. The vendor will be responsible for the geolocation algorithm.
GLMPORD94	3.2.3.4.0-3	The GLM error in pointing knowledge **shall** not exceed ±112 microradians, (± 56 microradians goal), which represent ½ and ¼ of an 8 km GSD, respectively.
GLMPORD95	3.2.3.5	**3.2.3.5 GLM Data Requirements**
GLMPORD96	3.2.3.5.0-1	The GLM **shall** contribute no more than 10 seconds (TBR) to the total data latency from detection through generation of level 1b products. Discussion: The GLM contribution to data latency includes delay of delivery of data to the spacecraft and delay due to ground algorithm processing (i.e. geo-location).
GLMPORD97	3.2.3.5.0-2	The GLM **shall** report each detected lightning event.
GLMPORD98	3.2.3.5.0-3	The GLM **shall** time tag each lightning event to an accuracy of 500 microseconds.
GLMPORD99	3.2.3.5.0-4	The GLM **shall** provide the intensity of each detected lightning event.
GLMPORD100	3.2.3.5.0-5	The GLM **shall** provide the threshold used to detect each lightning event.
GLMPORD101	3.2.3.5.0-6	The GLM **shall** provide the background intensity of each lightning event.
GLMPORD102	3.2.3.5.0-7	The GLM **shall** identify the active detector element(s) for each detected lightning event.

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GLMPORD103	3.2.3.5.0-8	The GLM **shall** provide background images (intensity of every detector element) autonomously once every (TBR) minutes, or upon ground command. Discussion: This data should prove valuable for coastline navigation verification and for on orbit threshold setting/performance verification.
GLMPORD261	3.2.3.5.0-9	The readout of a background image **shall** not interfere with the detection and reporting of lightning events.
GLMPORD265	3.2.3.5.0-10	The time to perform the readout of a background image **shall** be scaled to accommodate the allowable GLM observatory to ground data rate, while performing continuing lightning detection.
GLMPORD104	3.2.3.5.0-11	The GLM **shall** provide engineering data, including spacecraft position, attitude and rate data, health and safety telemetry, and diagnostic data.
GLMPORD105	3.2.3.6	**3.2.3.6 GLM On-board Calibration Requirements**
GLMPORD106	3.2.3.6.0-1	The GLM **shall** provide an injected electronics calibration signal to check the linearity of the electronics and analog-to-digital converters.
GLMPORD107	3.2.3.6.0-2	The GLM injected calibration signal input non-linearity **shall** vary from a linear best fit by no more than 0.1 percent over the full dynamic of the GLM.
GLMPORD108	3.2.3.6.0-3	The dynamic range of the GLM injected calibration signal **shall** exceed the dynamic range of the GLM.
GLMPORD109	3.2.3.6.0-4	The GLM injected calibration signal **shall** be inserted as close to the detector output signal in the electronic chain as practicable.
GLMPORD110	3.2.3.6.0-5	The GLM electronic calibration sequence **shall** be initiated by ground command or observatory timed, stored command.
GLMPORD111	3.3	**3.3 Design Requirements**
GLMPORD112	3.3.1	**3.3.1 Reliability**
GLMPORD113	3.3.1.0-1	The GLM **shall** demonstrate by analysis a Reliability (R) of at least 0.6 after 10 years of on-orbit operations, preceded by up to 5 years of ground storage and up to 5 years of on-orbit storage.
GLMPORD114	3.3.1.0-2	The GLM **shall** demonstrate by analysis a Mean Mission Duration (MMD) of 8.4 years (TBR) for a design life of 10 years.
GLMPORD115	3.3.1.0-3	The GLM **shall** provide redundancy to eliminate all credible single-point failures.
GLMPORD116	3.3.1.0-4	The GLM redundant components **shall** be selectable by external command only.
GLMPORD117	3.3.1.0-5	The GLM units of any Flight Model **shall** be interchangeable, without modification, with the equivalent units of any other GLM Flight Model.
GLMPORD118	3.3.1.0-6	The GLM **shall** withstand without damage the sudden removal of operational power.
GLMPORD119	3.3.2	**3.3.2 Mechanical Requirements**

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GLMPORD120	3.3.2.0-1	Each GLM unit structure **shall** possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements.
GLMPORD121	3.3.2.0-2	The structure **shall** withstand all limit loads without loss of any required function. Limit loads are defined as all worst case load conditions including acceleration, vibration and temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch and on-orbit operations and storage.
GLMPORD122	3.3.2.0-3	The GLM structures **shall** withstand redistribution of internal and external loads resulting from nonlinear effects including deflections under load.
GLMPORD123	3.3.2.0-4	The GLM structures **shall** support yield loads without detrimental permanent deformation. Yield loads are limit loads multiplied by the appropriate protoflight yield factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype yield factor of safety is 1.4.
GLMPORD124	3.3.2.0-5	While subjected to any operational load up to yield operational loads, the resulting deformation **shall** not interfere with the operation of the GLM flight units. Operational load is defined as the expected on-orbit loads while the GLM is operating.
GLMPORD125	3.3.2.0-6	The GLM structures **shall** support ultimate loads without fracture or collapse for at least 3 seconds including ultimate deflections and ultimate deformations of the flight unit structures and their boundaries. When proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Ultimate loads are limit loads multiplied by the appropriate protoflight ultimate factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype ultimate factor of safety is 1.6.
GLMPORD126	3.3.2.0-7	Stiffness of the GLM structures and their attachments **shall** be determined by their performance requirements and their handling, transportation and launch environments.
GLMPORD127	3.3.2.0-8	Special stowage provisions **shall** be used, if required, to prevent excessive dynamic amplification during handling, transportation and transient flight events.
GLMPORD128	3.3.2.0-9	The fundamental resonant frequency of each GLM sensor unit **shall** be 50 Hz (TBR) or greater when the GLM sensor unit is rigidly constrained at its spacecraft interface in its launch and operational configurations.
GLMPORD129	3.3.2.0-10	The fundamental resonant frequency of the GLM electronics unit(s) **shall** be 50 Hz or greater when the electronics unit(s) is rigidly constrained at the spacecraft interface.
GLMPORD130	3.3.2.0-11	Material properties **shall** be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.
GLMPORD131	3.3.2.0-12	Design values **shall** account for the probability of structural failures and loss of any required function due to material variability.
GLMPORD132 …	3.3.2.0-13	For critical members, design values **shall** be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence.

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GLMPORD132	3.3.2.0-13	Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units. Greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.
GLMPORD133	3.3.2.0-14	For redundant members, design values **shall** be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence. Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity. Greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.
GLMPORD134	3.3.2.0-15	The strength, detailed design, and fabrication of the structure **shall** prevent any critical failure, resulting in the loss of any mission objective, due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the GLM.
GLMPORD135	3.3.2.0-16	Accounting for the presence of stress concentrations and the growth of undetectable flaws, the GLM structures **shall** withstand loads equivalent to four complete service lifetimes.
GLMPORD136	3.3.2.0-17	While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual GLM structures **shall** not interfere with the operation of the GLM units.
GLMPORD137	3.3.2.0-18	After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures **shall** not interfere with the operation of the GLM units.
GLMPORD138	3.3.2.0-19	The GLM sensor unit **shall** provide a permanent flight worthy optical alignment reference composed of a minimum 2.54 cm alignment cube and a mounting surface datum.
GLMPORD139	3.3.2.0-20	The GLM **shall** provide a flight worthy cover for the optical alignment cube. Flight worthy cover means that the cover will capture the cube should it separate from the spacecraft during launch.
GLMPORD140	3.3.2.0-21	The GLM sensor unit **shall** provide fiduciary marks locating the X, Y, and Z axes of the
GLMPORD141	3.3.3	**3.3.3 Mechanisms**
GLMPORD142	3.3.3.0-1	Deployment, sensor, pointing, drive or separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.
GLMPORD143	3.3.3.0-2	GLM mechanisms **shall** meet performance requirements while operating in an Earth gravity environment with any orientation of the gravity vector (TBR).
GLMPORD144	3.3.3.0-3	GLM moving mechanical assemblies **shall** provide torque and force ratios per section 2.4.5.3 of GEVS using a NASA approved classification of each instrument mechanism.
GLMPORD145	3.3.3.0-4	Rotational GLM actuators **shall** provide a continuous maximum torque output greater than 7.0 milli-Nm for all operating points of the actuators.
GLMPORD146	3.3.3.0-5	Linear GLM actuators **shall** provide a continuous maximum force output greater than 0.28 N for all operating points of the actuators.

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GLMPORD147	3.3.3.0-6	GLM mechanisms using closed-loop control **shall** provide gain and phase margins greater than 12 dB and 40°, respectively, including the effects of the dynamic properties of any flexible structure.
GLMPORD148	3.3.3.0-7	GLM mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.
GLMPORD149	3.3.3.0-8	GLM mechanisms requiring restraint during launch **shall** be released from the caged condition by command.
GLMPORD150	3.3.3.0-9	GLM mechanisms requiring restraint during launch **shall** be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.
GLMPORD151	3.3.4	**3.3.4 Thermal Requirements**
GLMPORD152	3.3.4.0-1	The GLM contractor **shall** establish Mission Allowable Temperatures (MAT) for the GLM accommodating at least 5 K of analytical/test uncertainty at each temperature extreme. Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.
GLMPORD153	3.3.4.0-2	The GLM **shall** maintain thermally independent units and their internal components within MAT limits during all flight operational conditions including bounding worst-case environments.
GLMPORD154	3.3.4.0-3	The GLM **shall** survive without damage over the Non-Operational Temperatures (NOT) range extending from at least 20° K warmer than the hot MAT and at least 20° K colder than the cold MAT.
GLMPORD155	3.3.4.0-4	The GLM cold NOT **shall** be 248° K or colder.
GLMPORD156	3.3.4.0-5	The GLM **shall** provide two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.
GLMPORD157	3.3.4.0-6	The GLM heaters **shall** be sized to provide 25% margin for worst case conditions.
GLMPORD158	3.3.4.0-7	The GLM survival heaters **shall** be thermostatically controlled.
GLMPORD159	3.3.5	**3.3.5 Onboard Processors Requirements**
GLMPORD160	3.3.5.0-1	The entire GLM flight software image **shall** be contained in non-volatile memory at launch.
GLMPORD161	3.3.5.0-2	The GLM **shall** provide for reset of the On-board Processor by command.
GLMPORD162	3.3.5.0-3	The GLM On-Board Processor **shall** initialize upon power-up into a predetermined configuration.
GLMPORD163	3.3.5.0-4	The GLM **shall** provide a fail-safe recovery mode dependent on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.
GLMPORD164	3.3.6	**3.3.6 Flight Software Requirements**

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GLMPORD165	3.3.6.0-1	All software developed for the GLM instrument **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. With NASA approval, minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers.
GLMPORD166	3.3.6.0-2	The GLM flight software **shall** be re-programmable on-orbit without computer restart.
GLMPORD167	3.3.6.0-3	The GLM flight software **shall** be uploadable in Computer Software Units (CSUs) and usable immediately after completion of the modified unit upload.
GLMPORD168	3.3.6.0-4	Activation of the modified GLM CSUs **shall** not require completion of an upload of the entire flight software image.
GLMPORD169	3.3.6.0-5	The GLM flight software **shall** be deterministic in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.
GLMPORD170	3.3.6.0-6	All GLM software data that are modifiable and examinable by ground operators **shall** be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.
GLMPORD171	3.3.6.0-7	The definition of GLM commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.
GLMPORD172	3.3.6.0-8	All GLM software and firmware versions **shall** be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.
GLMPORD173	3.3.6.0-9	The GLM software internal identifier **shall** be keyed to the configuration management process.
GLMPORD174	3.3.6.0-10	During development, GLM flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity): Flight Processor Resource Utilization Limits

	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%
ROM Memory	50%	60%	70%
CPU	40%	50%	60%

GLMPORD196	3.3.6.0-11	The GLM flight software **shall** provide time-tagged event logging in telemetry.
GLMPORD197	3.3.6.0-12	The GLM event messages **shall** include all anomalous events, mode transitions, and system performance events.
GLMPORD198	3.3.6.0-13	All GLM flight software components **shall** utilize a common format for event messages.
GLMPORD199	3.3.6.0-14	GLM flight software **shall** provide commands to enable and disable queuing of individual event messages.

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GLMPORD200	3.3.6.0-15	GLM flight software **shall** buffer a minimum of 1000 event messages (TBR) while the event messages are queued for telemetering to the ground.
GLMPORD201	3.3.6.0-16	The GLM event message queue **shall** be configurable by command to either (a) discard the new events, or (b) overwrite oldest events when the queue is full.
GLMPORD202	3.3.6.0-17	GLM flight software **shall** maintain counters for: a) the total number of event messages generated b) the number of event messages discarded because of queue overflow c) the number of event messages not queued due to being disabled
GLMPORD203	3.3.6.0-18	GLM flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.
GLMPORD204	3.3.6.0-19	GLM flight software **shall** provide a mechanism to verify the contents of all memory areas.
GLMPORD205	3.3.6.0-20	GLM flight software, and associated on-board computer hardware, **shall** provide for dumping any location and any size of on-board memory to the ground upon command.
GLMPORD206	3.3.6.0-21	The GLM flight software memory dump capability **shall** not disturb normal operations and instrument data processing.
GLMPORD207	3.3.6.0-22	Telemetry points sampled by the GLM **shall** be controlled by an on-orbit modifiable table.
GLMPORD208	3.3.6.0-23	The sample rate of every GLM telemetry point **shall** be controlled by an on-orbit modifiable table.
GLMPORD209	3.3.7	**3.3.7 Power Requirements**
GLMPORD210	3.3.7.0-1	The GLM power regulators and supplies **shall** provide a phase margin of greater than 35 degrees.
GLMPORD211	3.3.7.0-2	The GLM power regulators and supplies **shall** provide a gain margin of greater than 20 dB.
GLMPORD212	3.3.7.0-3	The GLM **shall** not contain fuses.
GLMPORD213	3.3.7.0-4	The GLM **shall** provide flight qualified covers for all test point connectors.
GLMPORD214	3.3.8	**3.3.8 Magnetic Properties**
GLMPORD215	3.3.8.0-1	The change in the magnetic field produced by the GLM sensor, electronics, or power supply modules **shall** be less than 30 nanotesla peak-to-peak for any operating mode, up to a low-pass bandwidth of 4.0 Hz, along any axis when measured at a distance of 1 meter from any face of a module.
GLMPORD216	3.3.9	**3.3.9 Spacecraft Level Ground Testing**
GLMPORD217	3.3.9.0-1	The GLM **shall** accommodate operational testing in all modes and states for indefinite periods during Spacecraft level Thermal Vacuum in at least the following two orientations: 1) Spacecraft +Y axis aligned with the gravity vector and pointed down. 2) Spacecraft -X axis aligned with the gravity vector and pointed down.
GLMPORD218	3.3.10	**3.3.10 Electrical System Test Equipment**

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GLMPORD219	3.3.10.0-1	The Electrical System Test Equipment (ESTE) **shall** operate the GLM and electrical ground support equipment during performance verification and calibration testing.
GLMPORD220	3.3.10.0-2	The ESTE **shall** simulate the spacecraft interface with power, clock pulses, command, and telemetry functions.
GLMPORD221	3.3.10.0-3	The ESTE **shall** include all test equipment necessary to operate and control the GLM in all phases of operation and test modes.
GLMPORD222	3.3.10.0-4	The ESTE **shall** generate and maintain command logs.
GLMPORD223	3.3.10.0-5	The ESTE **shall** limit check all health and safety data.
GLMPORD224	3.3.10.0-6	The ESTE **shall** capture and archive all raw GLM data.
GLMPORD225	3.3.10.0-7	The ESTE **shall** provide near-real time and off line data analysis of all GLM data necessary to determine the performance characteristics of the instrument.
GLMPORD226	3.3.10.0-8	The ESTE **shall** interface with the Spacecraft Ground Support Equipment at the Spacecraft Contractor’s facility to extract GLM science and engineering data.
GLMPORD227	3.3.10.0-9	The ESTE **shall** prohibit hazardous or critical commands being sent to the GLM without operator verification.
GLMPORD228	3.3.11	**3.3.11 Flight Software Development Environment**
GLMPORD229	3.3.11.0-1	The Flight Software Development Environment (FSDE) **shall** consist of the hardware and software systems used for real-time, closed loop testing on flight like hardware to develop, test, validate, and demonstrate the flight software is ready for Government acceptance.
GLMPORD230	3.3.11.0-2	The FSDE **shall** support all lifecycle activities (development, test, and validation) simultaneously.
GLMPORD231	3.3.11.0-3	The FSDE **shall** contain all items (software, databases, compilers, debuggers, etc.) needed to prepare flight software for the target processor.
GLMPORD232	3.3.11.0-4	The FSDE **shall** contain engineering (hardware) models of necessary flight hardware as well as dynamic software models comprising the remainder of the instrument and the necessary on-orbit environment.
GLMPORD233	3.3.12	**3.3.12 Shipping Containers**
GLMPORD234	3.3.12.0-1	The GLM shipping container **shall** be compatible with shipment by air or air-ride van.
GLMPORD235	3.3.12.0-2	The GLM shipping container **shall** be purgeable, and electrically equipped for testing instrument aliveness while in storage, without opening.
GLMPORD236	3.3.12.0-3	The GLM shipping container **shall** have internal temperature, humidity, and pressure monitors with external indicators.
GLMPORD237	3.3.12.0-4	The GLM shipping container **shall** have shock recorders.
GLMPORD238	3.3.12.0-5	The GLM shipping container **shall** meet all contamination control requirements imposed on the GLM instrument units.
GLMPORD239	3.3.12.0-6	The GLM GSE shipping container(s) **shall** be compatible with shipment by air or air ride

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GLMPORD242	3.3.13	**3.3.13 GLM Emulator**
GLMPORD243	3.3.13.0-1	The GLM emulator **shall** simulate all instrument modes and mode transitions.
GLMPORD244	3.3.13.0-2	The GLM emulator **shall** simulate predefined, scripted anomalies.
GLMPORD245	3.3.13.0-3	The GLM emulator **shall** communicate with a spacecraft emulator for instrument command, telemetry, and science packets using Space Wire.
GLMPORD246	3.3.13.0-4	The GLM emulator **shall** use commercial power.
GLMPORD247	3.3.13.0-5	The GLM emulator **shall** execute GLM flight code.
GLMPORD248	3.3.13.0-6	The GLM emulator **shall** accept simulation control commands from a standalone console.
GLMPORD249	3.3.13.0-7	The GLM emulator **shall** accept simulation control commands from the spacecraft
GLMPORD250	3.3.13.0-8	The GLM emulator **shall** generate housekeeping data reflective of commanded mode.
GLMPORD251	3.3.13.0-9	The GLM emulator **shall** accept real-time inputs to change simulated telemetry or modeling parameters.
GLMPORD252	3.3.13.0-10	The GLM emulator **shall** maintain a log of all instrument commands received indicating validity, command mnemonic, and raw bit pattern.
GLMPORD253	3.3.13.0-11	The GLM emulator **shall** maintain a log of all simulation directives received.

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GLMPORD254	4	**4 Acronyms**

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GLMPORD255	4.0-1	A/D	analog-to-digital
		ABI	Advanced Baseline Imager
		ANSI	American National Standards Insititute
		AR	acceptance review
		CDR	critical design review
		cm	centimeter
		CONUS	continental United States (excluding Alaska and Hawaii)
		CPU	central processing unit
		CSU	computer software units
		CTE	coefficient of thermal expansion
		EOL	end-of-life
		ESD	electrostatic discharge
		ESTE	electrical system test equipment
		FOV	field-of-view
		FSDE	flight software development environment
		GEVS	General Environmental Verification Specification
		GIRD	General Interface Requirements Document
		GLM	Geostationary Lightning Mapper
		GOES	Geostationary Operational Environmental Satellite
		GS	ground system
		GSD	ground sample distance
		GSE	ground support equipment
		INR	image navigation and registration
		ISO	International Organization for Standardization
		J	joules
		K	Kelvin
		km	kilometers
		LIS	Lightning Imaging Sensor
		LMS	Lightning Mapping Sensor
		m	meters
		MAT	mission allowable temperature
		MMD	mean mission duration
		MRD	Mission Requirements Document
		ms	milliseconds
		N	Newtons
		NASA	National Aeronautics and Space Administration
		NBOF	narrow-band optical filter
		NEDN	noise equivalent delta radiance
		nm	nanometer
		Nm	Newton-meter
		NOAA	National Oceanic and Atmospheric Administration
		NOT	non-operating temperature
		OTD	Optical Transient Detector
		PDR	Preliminary Design Review
		PORD	Performance Operational Requirements Document
		RAM	random access memory
		ROM	read-only memory
		SNR	signal-to-noise ratio
		sr	steradian
		S/W	software
		TBD	to be determined
		TBR	to be reviewed
		TBS	to be supplied
		TRMM	Tropical Rainfall Mapping Mission
		UIID	Unique Instrument Interface Document

Attachment 1 Document Change Record

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